REVIEW ARTICLE

Partially Hydrolyzed Guar Gum: Clinical Nutrition Uses

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OBJECTIVE: This paper provides a review of research on partially hydrolyzed guar gum that is relevant to clinical nutrition practice.

METHODS: All relevant papers published on partially hydrolyzed guar gum were reviewed and the results summarized.

RESULTS: Partially hydrolyzed guar gum (PHGG) is a water-soluble dietary fiber with a wide range of uses in clinical nutrition. Its low viscosity allows its use in enteral products and beverages. PHGG can be added to enteral formulas and food products as a dietary fiber source. PHGG provides the benefits associated with dietary fiber ingestion. Addition of PHGG to the diet reduced laxative dependence in a nursing home population. PHGG also reduced the incidence of diarrhea in septic patients receiving total enteral nutrition and reduced symptoms of irritable bowel syndrome. PHGG also increased production of Bifidobacterium in the gut.

CONCLUSION: The ease of use of PHGG and its clinical effectiveness make it a good choice in clinical nutrition practice. *Nutrition* 2003;19:549–552. ©Elsevier Inc. 2003

KEY WORDS: dietary fiber, partially hydrolyzed guar gum, laxation, short chain fatty acids

DIETARY FIBER

Dietary fiber is difficult to define and difficult to analyze. For labeling the dietary fiber content of food products within the United States, dietary fiber is defined as the material isolated by analytical methods approved by the Association of Official Analytical Chemists.[1] Newer definitions have defined dietary fiber as any carbohydrate that gets into the gut, even if that carbohydrate is not analytically dietary fiber.[2] As part of the federally mandated evaluation of the dietary reference intakes, the Food and Nutrition Board appointed a panel to develop a proposed definition of dietary fiber for North America.[1] The Panel on the Definition of Dietary Fiber proposed two new definitions: dietary fiber and added fiber. Dietary fiber consists of non-digestible carbohydrates and lignin that are intrinsic and intact in plants. Added fiber consists of isolated, non-digestible carbohydrates that have beneficial physiologic effects in humans. Total fiber is the sum of dietary fiber and added fiber. The intent of these proposed definitions is to recognize the physiologic actions of fiber and its demonstrable health effects and to reduce the emphasis on dietary fiber as a constituent of food requiring quantification.[1]

These changes in the definition of dietary fiber will require that all isolated dietary fibers have clinical data that support their effectiveness. The intent of this review is to summarize the physiologic data for partially hydrolyzed guar gum (PHGG).

JUSTIFICATION FOR ISOLATED FIBER SOURCES

Recommendations for adult dietary fiber intake fall in the range of 20 to 35 g/d.[3] Although based on limited clinical data, the recommendation for children older than 2 y is to increase dietary fiber intake to an amount equal to or greater than their age plus 5 g/d, to achieve intakes of 25 to 35 g/d after age 20 y.[4] Specific recommendations for the elderly have not been published, although a safe recommendation would be 10 to 13 g dietary fiber per 1000 kcal. No recommendations exist for fiber intake in several disease states or for patients in long-term care facilities. Dietary fiber can bind fluid, so all recommendations for increased fiber intake include recommendations for increased fluid intake. In addition, caution should be used when recommending fiber to those with gastrointestinal diseases, including constipation, because large increases in fiber consumption can lead to intestinal obstruction.

Dietary fiber intake continues to be at less than recommended amounts in the United States, with usual intakes averaging only 14 to 15 g/d.[5] Many popular American foods contain little dietary fiber. Servings of commonly consumed grains, fruits, and vegetables contain only 1 to 3 g of dietary fiber.[6] Legumes and high-fiber bread and cereal products supply more dietary fiber but are not commonly consumed. The new broadened definition of dietary fiber should increase the use of added fibers as food ingredients and supplements. To qualify as an added fiber, isolated fibers will have to show a physiologic effect.

WHAT IS PHGG?

PHGG is a natural, water-soluble dietary fiber. The guar plant, *Cyamoposis tetragonolobus*, has been grown in India and Pakistan since ancient times.[7] Since the 1950s, the seeds of the guar plant have been processed into guar gum and used as a food additive. Guar gum is the galactomannan of the endosperm of guar seeds. Galactomannans are present in a variety of sources in nature.[8] Other plants that contain galactomannans are locust bean gum, alfalfa seeds, coconut meat, soybeans, pineapple, sugar beets, and coffee beans.[8] In the food industry, guar gum is used as a thickening and stabilizing agent in a wide variety of foods, usually in amounts less than 1% of food weight.

Although guar gum has positive physiologic benefits, its high viscosity makes it difficult to incorporate into food products and

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enteral solutions. PHGG was produced to provide a dietary fiber source that could be added easily to the diet and would be acceptable to consumers.

PHGG is produced by controlled partial enzymatic hydrolysis of guar gum. PHGG has a smaller molecular weight and less viscosity than native guar gum. PHGG is stable, does not hold much water, and has a bland flavor.[8] It is soluble at the pH levels commonly found in foods. PHGG has been used in cereals, juices, shakes, yogurt, meal replacements, soups, and baked goods and as a fiber source in enteral nutrition products. PHGG has undergone extensive toxicity testing and found to be safe.[9] Dietary levels up to 10% PHGG were tolerated by laboratory animals without any signs of toxicity.[10] In addition, in 1993, the Life Sciences Research Organization of the Federation of American Societies for Experimental Biology commissioned a panel of six experts to assess the use of PHGG in consumer foods.[11] The experts concluded that a daily consumption of PHGG at levels up to 20 g/d was safe.

PHYSIOLOGIC BENEFITS OF FIBER CONSUMPTION, INCLUDING PHGG

Diarrhea and Constipation

Fiber increases stool weight and promotes normal laxation.[12] Stool weight increases as fiber intake increases, but the additional fiber tends to normalize defecation frequency to one daily and gastrointestinal transit time to between 2 and 4 d.[13] The increase in stool weight is caused by the presence of the fiber, by the water that the fiber holds, and by partial fermentation of the fiber, which increases the amount of bacteria in stool.[14] If the fiber is rapidly fermented in the large bowel, as are most soluble fiber sources, there is little increase in stool weight.[12] The moisture content of human stool is 70% to 75%, and this does not change when more fiber is consumed.[15] Fiber in the colon is no more effective than the other components of stool at holding water in the lumen.

Dietary fiber sources are thought to normalize the gastrointestinal environment and as such can be effective at treating constipation and diarrhea. Unfortunately, there are no standardized, accepted definitions for either condition. Constipation is a prevalent, chronic condition in Western society, a common clinical complaint but a poorly studied condition. Constipation has been defined as fewer than three bowel movements per week, although most people define constipation as fewer than one bowel movement per day. The frequency of defecation is only one aspect of constipation. Ease of passage of stools and lack of straining are other components of normal laxation. Bowel habit is affected by other variables, including medications, stress, exercise, the volume of food, the type of food, hormones, and other environmental factors that make it difficult to study and a difficult clinical condition to treat. Although subjective measures of bowel function are important variables to collect, objective measures such as weight and dry stool weight, gastrointestinal transit time, and frequency of defecation are useful biomarkers to study.

We compared the gastrointestinal effects of PHGG with those of soy polysaccharide in 11 healthy men.[16] Subjects consumed 15 g/d of each fiber source in enteral diets, and each treatment lasted 18 d. Stool samples were collected during the treatments and during habitual diet consumption. Stool weights were highest when subjects consumed their usual, whole food diets. There were no differences in the enteral diets containing soy polysaccharide treatment and the PHGG treatment. Thus, PHGG performed similarly to soy polysaccharide, a dietary fiber high in insoluble fiber that is commonly used as a fiber source in enteral products.

PHGG has also been evaluated in constipated subjects. PHGG was administered as a beverage (11 g/d) to 15 constipated women for 3 wk.[17] Defecation frequency, pH, stool weight, stool moisture, and bacterial flora of the feces were investigated and compared with the control periods. Average total dietary fiber intake from food was about 10 g/d. PHGG increased defecation frequency from 0.46 to 0.63 per day. Fecal moisture significantly increased from 69% in the control period to 74% with PHGG. Fecal moisture content also increased, consistent with the lowering of the fecal pH. The PHGG treatment significantly increased *Lactobacillus* spp. occurrence in feces.

PHGG was evaluated in a nursing home setting as a replacement for regular laxative use.[18] During the baseline period, laxative use, defecation frequency, and other health factors were recorded. After 3 wk, the subjects were changed to PHGG for 1 wk. The consumption goal was 15 g/d of PHGG to be taken in three equal doses. During this time, the subjects' laxative intakes were cut in half. After the transition period was completed, all laxative intake was stopped. The test period continued for another 4 wk. The use of laxatives dropped from an average of 2.0 doses per day at baseline to 0.2 doses per day during the PHGG-supplementation period. There was no difference in defecation frequency during the study. These studies supported the notion that PHGG can be helpful in the treatment of constipation. An additional benefit of PHGG is that it is easily added to enteral formulas and well accepted by patients.

PHGG was evaluated as a treatment for irritable bowel syndrome.[19] The investigators studied 134 outpatients with a mean range of 2 to 35 weekly evacuations. Consumption of 5 g/d of PHGG decreased the frequency of irritable bowel symptoms such as flatulence, abdominal tension, and abdominal spasms. The researchers conclude that PHGG works well in cases of altered intestinal motility and is easy to use because of its non-gelling properties.

Gastrointestinal side effects, in particular diarrhea, are often the reasons for discontinuation of enteral nutrition. Unfortunately, there are no standard, accepted ways of defining diarrhea.[20] The reported incidence of diarrhea in tube-fed patients ranges from 2% to 63%. Stool frequency, stool consistency, and stool quantity are the three features of bowel elimination usually used to define diarrhea. In addition to fiber, oral agents such as sorbitol and magnesium have been suggested as important intake variables affecting stool consistency. Dietary fiber also may improve fecal incontinence. Patients with fecal incontinence who consumed dietary fiber as psyllium or gum arabic had significantly fewer incontinent stools than those who used placebo.[21] Improvements in fecal incontinence or stool consistency did not appear to be related to unfermented dietary fiber.

Homann et al.[22] evaluated diarrhea incidence when patients receiving total enteral nutrition were supplemented with 20 g/d of PHGG. The patients receiving total enteral nutrition with soluble fiber had decreased diarrhea but increased flatulence. Four patients receiving the non-supplemented enteral formula had diarrhea that necessitated stopping enteral feeding, and none of the supplemented patients had diarrhea. The investigators suggested the production of short-chain fatty acids associated with the soluble fiber as an explanation for the reduction in diarrhea incidence.

Alam et al.[23] evaluated PHGG added to oral rehydration solution in treatment of acute diarrhea in children. A double-blind, randomized, controlled clinical trial was conducted in 150 boys aged 4 to 18 mo who had watery diarrhea of less than 48 h in duration. After admission, boys were assigned to receive the World Health Organization Oral Rehydration Solution or the same solution supplemented with PHGG. Patients receiving the supplemented fluid had significantly reduced duration of diarrhea compared with the control group. There was less stool output daily from days 2 through 7 in boys treated with the PHGG-supplemented solution. PHGG substantially reduced the duration of diarrhea and modestly reduced stool output in acute non-cholera diarrhea in young boys, thus supporting its use as an antidiarrheal therapy for acute diarrhea in children.

Recently, PHGG was found to reduce the incidence of diarrhea in septic patients receiving total enteral nutrition.[24] A prospective, double-blind, randomized trial was conducted in patients with

severe sepsis and septic shock. Patients were randomly assigned to a usual enteral formula or an enteral formula that contained 22 g of PHGG per liter. All patients were mechanically ventilated and treated with catecholamines and antibiotics. Enteral feeding was provided through a nasogastric tube for a minimum of 6 d. The mean frequency of days with diarrhea was significantly lower in patients receiving fiber than in those on standard alimentation (8.8 ± 10.0% versus 32.0 ± 15.3%, mean ± standard deviation). The entire group of fiber-fed patients had fewer days with diarrhea per total feeding stays. The researchers concluded that total enteral nutrition supplemented with soluble fiber is beneficial in reducing the incidence of diarrhea in tube-fed, fully resuscitated, and mechanically ventilated septic patients.

Fermentation

The model proposed for the beneficial effects of fiber in enteral feeding, that fiber is fermented by anaerobic intestinal bacteria that generate short-chain fatty acids, which serve as energy sources for colonic mucosal cells, is probably correct.[25] Studying the physiologic effects of dietary fiber, especially in a sick population, is extremely difficult. Most studies have been too short, measurements have been semiquantitative, and dietary fiber and short-chain fatty acid levels frequently have not been measured. It is not possible to study the gut environment in a free-living human, and results from animal studies are often suspect because of significant differences in gastrointestinal physiology.

We evaluated the in vitro effects of various fibers on short-chain fatty acid production in a batch fermentation system.[26] Results indicated that PHGG after 24 h produced the highest levels of total short-chain fatty acids when compared with other commonly used fiber supplements. Although in vitro studies must be interpreted cautiously, these results supported the idea that the beneficial effects seen with PHGG in vivo may be a result of short-chain fatty acid production.

Fermentable dietary fibers are thought to alter the gut environment with the production of short-chain fatty acids and changes in the gut microflora. PHGG, similar to other dietary fibers, increases the concentration of Bifidobacterium in the gut.[27] When PHGG was given to human subjects, the percentage of Bifidobacterium in feces increased from 14.7% in the control diet to 31.7% in the PHGG treatment.[28] The ability of dietary fibers to alter the gut microflora is considered a prebiotic effect and may improve immunologic status. Consumption of PHGG also decreased β-glucuronidase activity, putrefactive products, and ammonia content of feces. PHGG consumed with fructo-oligosaccharides in the form of a biscuit also was found to have a prebiotic effect.[29]

Mineral Absorption

Another health benefit of fermentable carbohydrate is improved mineral absorption. Although dietary fibers have traditionally been thought to decrease absorption of minerals, the more soluble, fermentable fiber sources do not appear to bind minerals and limit their absorption. In fact, some research has supported the idea that fermentable carbohydrates enhance absorption of minerals. Research for improved mineral absorption with PHGG has been generated with the rat experimental model.[30,31]

Possible mechanisms whereby PHGG would improve calcium absorption have been described by Scholz-Ahrens et al.[32] At the gastrointestinal level, PHGG passes through the small intestine and reaches the cecum and colon, where fermentation takes place. This fermentation results in production of short-chain fatty acids and a decrease in gut pH that may improve calcium absorption in the gut. At the villus level, the villus crypt height, number of epithelial cells per crypt, cecal vein flow, and mucosal to serosal calcium fluxes are increased by fermentable carbohydrate. At the cellular level, the expression of calbindin-D9K is stimulated; hence, the active calcium transport route is enhanced.

PHGG was found to significantly decrease the incidence of bacterial translocation when compared with enteral formula without added fiber.[33] This mouse study suggested that fiber-supplemented enteral formulas may be beneficial in clinical patients with bacterial overgrowth.

POTENTIAL NEGATIVE EFFECTS OF DIETARY FIBER

Potential negative effects of dietary fiber include reduced absorption of vitamins, minerals, proteins, and calories. It is unlikely that healthy adults who consume fiber in amounts within the recommended ranges will have problems with nutrient absorption; however, dietary fiber recommendations of 25 g/d may not be appropriate for children and the elderly because so little research has been conducted in these populations.

Fermentation of dietary fiber by anaerobic bacteria in the large intestine produces gas, including hydrogen, methane, and carbon dioxide, which may be related to complaints of distention or flatulence. When dietary fiber is increased, fluid intake also should be increased, and fiber should be increased gradually to allow the gastrointestinal tract time to adapt. Further, normal laxation may be achieved with smaller amounts of dietary fiber, and the smallest dose that results in normal laxation should be accepted.

Fiber-enriched enteral formulas may cause blockages in small-bore feeding tubes. This is most problematic with gums and other viscous fibers. Formulas containing fiber tend to be more expensive than standard formulas, making them a difficult choice in the absence of compelling clinical data. Few data have been published on the effectiveness of fiber-containing formulas in the long-term setting, and less expensive and more effective laxation aids are available.

Research-based recommendations about which patients are good candidates for fiber-containing enteral formulas cannot be made. Tube-fed patients with constipation or diarrhea who are known to have otherwise healthy gastrointestinal tracts should be considered candidates for fiber-containing enteral formulas. Because of the potential protective role of fiber against diverticulosis, colon cancer, diabetes, and heart disease, a fiber-enriched enteral formula may be indicated for patients using long-term enteral feeding. Fiber-containing enteral formulas may work better for certain patients, and they should be used if they produce positive results. Clinicians should be cautious in prescribing fiber-containing enteral products. Because of the wide individual variability of responses to dietary fiber and the potential problems with large doses, the smallest dose of dietary fiber that produces the desired result should always be used.

In general, dietary fiber in recommended amounts should normalize transit time and be helpful when constipation or diarrhea is present. Although obtaining dietary fiber from whole foods is preferable because it is accompanied by additional nutrients and phytochemicals, a fiber supplement should be recommended to close the fiber gap. Additional research is needed on the ability of different dietary fibers to improve the gastrointestinal environment and their effect on mineral absorption. To improve compliance, fiber supplements must be easily incorporated into the diet whether they are consumed as a supplement or added to food.

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